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ABSTRACT

In this study, a mathematical model is used to tie both direct and indirect industrial pollution generated by fluctuations of the entire economy to behavioral patterns of the consuming public. The model studies consumer behavior patterns from three viewpoints: income of family, age of head of family, and regional location of family within the United States. The methodology relates 126 final consumption industry groupings to 48 consumer item (product) groupings of the National Conference Board's taxonomy. The heart of the methodology employs the Resources for the Future's "National Pollution Model", basically an input-output plus residual technique. Findings focus on most polluting industries, and the pollution associated characteristics of sub-groups of the U.S. population. (Author/BB)

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STUDIES IN ENVIRONMENT

Volume IV

Consumption Differentials and the Environment

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ABSTRACT

Campaigns to clean up the environment traditionally focus on sources of pollution for possible ways of changing or adding to industrial processes as a means to reduce or abate undesirable residuals in the atmosphere, water courses and in the land. Quick remedial actions often are obtained in this manner. These solutions, however, often require constant maintenance of retrofitted devices and technologies used in production and monitoring of results. Sometimes longer lasting results can be obtained with less attention to maintenance and monitoring aspects when substitutions of material inputs can be made. But fundamentally, pollution - whatever the source - is a direct reflection of the behavioral patterns of the comsuming public. In order to achieve long lasting positive reductions of pollutants, basic attitudinal changes must be effected toward what goods and services are demanded, in what quantities, as well as attitudes toward usage and disposal of these items. It is this last area in which this report makes initial contributions.

Through the use of a mathematical model, both direct and indirect industrial pollution generated by fluxuations of the entire economy are tied to behavioral patterns of the consuming public. The model studies consumer behavior patterns from three viewpoints: income of family, age of head of family, and regional location of family within the United States. The methodology relates 126 final consumption industry groupings to 48 consumer item (product) groupings of the National Conference Board's taxonomy. The heart of the methodology employs the Resources for the Future's "National Pollution Model", basically an input-output plus residual technique.

Findings focus on most polluting industries, and the pollution associated characteristics of sub-groups of the U.S. population.

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SECTION I
CONCLUSIONS

The major conclusions of this study are:

1) For each of the 12 types of pollutants considered separately, concentration patterns emerged where the highest ten consumer items represent 30-55% of all consumer expenditures and 65-95% of all pollution.

2) For all consumer pollution categories considered as a whole, ten items were found to contribute the major proportion. These were:

- Meat, Poultry and Eggs
- Apparel
- Autos, Parts and Repair
- Dairy Products
- Shelter and other Realty
- Home Utilities
- F[illegible]its and Vegetables
- C[illegible]eals and Bakery
- Toiletries
- Insurance

3) The highest income groups over-consume on these top ten consumer items, and therefore over-contribute to pollution caused in the production of these items relative to their proportion of the population.

4) The consumer groups with age-of-head of household 35-54 over contribute to pollution by their consumption habits, and groups with age-of-head of household under 25 and over 65 undercontribute, relative to their proportions in the population.

5) Regional consumption patterns showed no significant differences which were not accounted for in the analysis of income and age-of-head household groups.

6) Food items show relatively little over-consumption.

7) Toiletries and shelter items show some over-consumption in highest income and middle-age groups.

8) Apparel, autos and insurance are luxury items and indicate high over-consumption patterns for certain consumer groups.

SECTION II
RECOMMENDATIONS

1) Reducation of specific types of pollution, should concentrate efforts on the highest consumer items, for that pollutant type.

2) The focal point in reducing overall pollution, should be the ten highest consumer items listed in conclusion 2.

3) Efforts to reduce pollution through alteration of consumption patterns should be concentrated on households earning over $10,000 per year, and with age-of-head of household 35-54.

4) Pollution reduction efforts directed at food items should concentrate efforts on production methods rather than on changing consumption patterns since food consumption is relatively inelastic.

5) Toiletries and shelter are relatively elastic and therefore more readily susceptible to efforts to affect changes in consumption patterns.

6) Apparel, autos, and insurance constitute luxury items, which are subject to high over-consumption, and thus highly susceptible to changes in consumption patterns.

SECTION III
INTRODUCTION

III.A The Consumption Model

The problem of pollution of the American environment has been approached from three basic perspectives: 1) overpopulation, 2) partialistic technology, and 3) profit practices of the industrial sector of the economy. Each of these perspectives, by approaching pollution from a different point of view, suggests its own particular solution to the problem: i.e., birth control measures, a systems approach to technological problems, and higher values placed on the use of common property resources. Each of these, in a sense, deals with one of the many aspects of the pollution problem, and in its own right, gives some insight into the overall problem. The increasing population, the increasing use of synthetic materials, and the increasing use of air, water, and land for disposal of industrial effluents, all play a part in the dramatic increase in pollution and its accompanying environmental and health problems.

Each, however, tends to ignore or discount the importance of the consumptive nature of the American society. While the U.S. contains only about 6% of the world's population, it consumes between 40% and 60% of the world's resources. These figures indicate that the problem of pollution can neither be properly nor completely analyzed and understood without taking into consideration the disproportionate consumption [usage and disposal] of energy and resources that characterizes American society.

The consumption model which follows presents a more comprehensive and integrated view of the problem of pollution, one in which the nature of consumption, as well as overpopulation, partialistic technology, and profit, is given appropriate consideration.

III.A.1 The Production-Consumption Flow

There is a basic flow of goods and materials in any society which serves the needs of the populace in terms of food, clothing, and shelter. As the society becomes more advanced, the needs also expand to include recreational, educational, and personal service needs, which must also be served through the economic system. In American society, as in most of the other advanced nations, this flow of goods and services to the consuming public constitutes the primary basis for the entire economy, and the strength of the nation is dependent on this very complex and interdependent system of products and services.

The flow of products can be thought of as roughly divided into two basic areas, production and consumption. The first segment of the cycle [production] begins with decisions regarding raw materials, the collection of those materials, the industrial decisions to make certain products in certain ways, the production of interindustry products and services, decisions regarding final production of consumer goods and services, and finally, the final production of those goods and services. The innumerable interindustry flows of materials and services [building, equipment, business services, etc.] are all aimed at filling intermediate steps in the flow of products and services to the consumer.

The connecting steps between production and consumption are the delivery and retailing of goods and services [marketing] to the consumer, and the purchase of those goods and services by the consumer.

The second area of flow, consumption, involves decisions regarding product usage, the actual usage of the goods and services, decisions regarding disposal, and the ultimate disposal. The various consumption decisions and processes constitute, in the aggregate, consumer demand, which functions as a feedback providing an input into the various production decisions. Insofar as the total production-consumption flow [Figure 1] is the basis of the economy, such a flow provides the most comprehensive approach to analyzing the problems of pollution.

III.A.2 Process Components of the Model

Pollution results from every process along the flow. The first process, the collection of raw materials needed to make the product by definition encompasses the excavation of mineral and chemical substances, the cutting and removal of lumber, and commercial catching of fish among others. Pollution from excavation includes such things as acid mine drainage, slag piles resulting from solid waste in the excavation process, and pollution resulting from the operation of machinery and equipment (both pollution from generation of electricity and the operation of internal combustion engines). Pollution from the cutting and removal of lumber includes particulates in air pollution, as well as suspended solids discharged into nearby bodies of water. Pollution from the fishing industry includes water pollution from oil spills, and solid wastes from the boats themselves.

The next process in the flow of goods to the consumer involves interindustry flows of materials, which includes the manufacturing of equipment, the construction of buildings, the delivery of agricultural products, the provision of business services, and the manufacturing of intermediary products prior to the inception of production for final demand. Pollution from the interindustry segment is characterized by typical air, water and land pollutants from manufacturing, business, and construction, as well as agricultural pollution (e.g., suspended and dissolved solids, and pesticides and herbicides).

The next process component is final production. This is defined to include only those activities and processes which directly result in goods or services which go directly to a final consumer (i.e., excludes all interindustry flows). Several types of pollution arise from final production, which includes the final manufacturing process of consumer items, the final processing of agricultural products and the processing of goods immediately prior to retailing. Among the pollutants attributable to the final production process are dissolved and suspended solids, organic compounds, carbon monoxide, and solid wast[illegible] though the final delivery of services results in le[illegible] pollution than the final production of goods, such pollution (including transportation and construction of buildings for retail activities) remains a significant problem.

The next segment of the flow entails the usage and disposal of goods and services. This is the first process where pollution is directly attributable to the consumer. Usage pollution involves such things as residential water usage, domestic electrical usage, pesticide and fertilizer usage, and solid waste generation. Usage pollution depends essentially on four factors: the frequency, mode, completeness or extent of product usage, and produ[illegible] quality or efficiency.

III.A.3 Decision Components of the Model

The decision components of the flow fall into two categories of production and consumption. There are three main production decisions: 1) raw material decisions, 2) interindustry production decisions, and 3) final production decisions. The two consumption decisions are: 1) purchase/usage decision and 2) disposal decision. There is obviously little or no direct pollution generated by these various decisions components. However these components are vital in that they determine the type and amount of pollution that will be produced by each of the processes. Any attempt to solve the problem of pollution must address itself to these decision points, since although pollution is a product of the various processes, it is ultimately caused or brought about by the decisions discussed above. What the consumptive model shows is that the decision maker, at any given decision point shares with all those decision makers that preceded him in the flow, the responsibility for the pollution caused by their combined decisions. For example the responsibility for pollution caused by the decision to strip-mine coal must be borne not only by the extractor, but also by the interindustry decision maker who demands coal to produce steel, as well as by the consumer who demands new and larger automobiles made of steel.

III.A.4 The Feedback Components

The first and most important feedback components are the demand feedback loops. Consumer demand has traditionally been viewed in terms of the effects of purchase decisions on the

final product decisions. The consumption model indicates quite clearly that demand feedback plays a greatly expanded role. Not only does consumer demand influence all the production decisions but a given production decision also influences the production decision(s) that precedes it. This is the rationale for the distribution of responsibility for pollution (indicated previously) among the various decision makers. The assessment of responsibility in the coal-steel-auto example is based on the interactions of this demand-feedback loop. The final consumer who voices his demands for an automobile, in a sense initiates the demands by the automobile industry producers for steel and electricity from other interindustry and raw material producers, and can be seen to share responsibility for the pollution caused in their production.

Recycling is the set of feedback loops into the industrial phase whereby raw materials or intermediary products used in making final products, are reclaimed for use at various stages in the industrial process. The solid waste which results after usage of the consumer item is a function of the type, frequency, and completeness of the usage method. These wastes can be differentially re-integrated into the industrial system depending on the original quality of the product, the various types of components, (e.g., metal, plastics, wood) which are used in combination to make the product, and differential technologies which can be applied to the recycling process. To a certain extent, the ease of recycling products should not be the primary concern in industrial planning. Rather, the primary concern should rest with the quality of the products so that product life will be extended, thus eliminating the power and resources necessary to return the recycled product to usable form.

III.A.5 Application of the Model

This model indicates that the demand for goods and services begins with the consumer. His demand for a final product feeds back to the final producer who must satisfy these demands. The final producer, in turn, makes demands on the interindustry producers for those goods and services which he needs to fulfill the consumer's demands. Interindustry producers, again, turn to the raw material producers for satisfaction of their demands for raw materials. In this way, the consumers' demand for final products feeds back along the flow to create the other demands for intermediate goods and services and raw materials.

It is obvious that the various production processes contribute to pollution. However, to the extent that the purpose of production is to satisfy demand, demand becomes the effective cause of pollution. Although this model places the greatest emphasis on consumer demand as the effective causal agent of pollution, this then does not absolve industry and its accompanying technology of its share of responsibility for the creation of new consumer items or new types of consumer services. Nor does the model attempt to quantify in

a specific manner the relative importance of each of these factors. It does, however, place more than nominal importance on the role of the consumer and his independent decision-making process.

Consumer demand begins in essentially two ways: First, the consumer originates demands to fulfill basic needs (food, shelter, clothing) in conventional forms. Second, convenience, price, and novelty, as engineered by new technologies and industries, tend to enlarge consumer markets and modify consumer demand through media/advertising. Original consumer needs stimulate production of new items to fill current needs in a better way. This new production or technology expands current consumer markets with lower prices and greater convenience. While advertising brings new products to the attention of the consuming public and helps to initiate needs which it can supply. In this way, the creation and modification of consumer demand sustains the flow of goods and services in the economy.

The question, "Who is really to blame for pollution?", remains the subject of heated debate. Arguments are based on the nature of biological systems, on the role of industry and economics in the society, on the morality of interference with individual freedom, and so on. Depending on the perspective, responsibility seems to shift from industrial organization, to overpopulation, to partialistic technology, or to inefficient or non-existant common-property resource management. This model however, takes a wider perspective, and sees responsibility resting with decision makers at all levels. The responsibility for pollution caused in the production of autos, from raw materials to final product, is shared by the final consumer as well as the decision makers at all levels of the production process who placed demands for goods and services on other industrial sectors for completion of the final product. This model, by centering on the entire production-consumption cycle, can focus attention on all the relevant contribution factors to the pollution. The industrial decisions to use particular production methods or materials, the ineffective control mechanisms for common resource use, the increasing number of consumers and their mounting product demands, can each be evaluted as to their influence on total pollution.

III.A.6 An Illustration of the Model in Use

A brief example of how the model traces the flow of goods from raw materials through final disposal will serve to illustrate both the flow of the model and the decision-making process whereby decisions affecting differential pollution are made. Paper lunch bags vs. steel lunch boxes can serve as an illustration of this cycle of demand, production, and use.

Let us assume, for the sake of simplicity that there is a demand by consumers for lunch containers, and that there are two kinds of lunch containers, paper bags and steel lunch boxes.

This consumer demand feedback for lunch containers thus places demands on the final producers who must decide which type of container, paper or metal, will be produced. On the basis of some marketing information the final lunch container producer decides to produce some mix of paper bags and metal boxes for the market. This final producer then places demands on the interindustry producer for equipment and machinery needed to manufacture the paper and steel which will go into them. This in turn places demands on the raw material producer for the wood and iron ore needed to make the two different materials. The felling of trees and the extraction of the iron ore, the manufacture of the machinery and equipment, and the final production of the lunch containers produces differential pollution at each of the production processes, depending on the material.

As the lunch containers are finally produced and delivered to market, the consumer exercises his perogative to choose which type of lunch container, if any, he will purchase. After purchase, the consumer will use his lunch container differentially. He will typically use the paper bag only once or twice, whereas he will probably use the steel lunch box repeatedly over a longer period of time. Finally, the consumer will dispose of the lunch container either by recycling or throwing the container away differentially. Following final disposal, the demand for another lunch container reoccurs. However, as the model indicates, the production demand influence affects the consumer demand for lunch containers (e.g., advertising may induce the consumer to switch from paper bags to steel lunch boxes). This change in demand would, through the demand feedback mechanism, affect all the production decisions.

Thus, the model clearly shows that the flow of goods and services from raw materials to final disposal is not linear and static, but rather circular and dynamic, constantly adjusting itself through the mechanism of the various feedback loops.

SECTION IV
METHODOLOGY

IV.A Production Data

The data dealing with the production sequence of the flow chart were obtained from previous studies by R. Ridker at Resources for the Future (RFF).[1] These studies began with an input-output model of the American economy, developed in the Bureau of Business and Economic Research at the University of Maryland, under the direction of Clopper Almon. This model contains some 185 production sectors, 126 of which go to personal consumption.[2] These sectors are defined in the model as special aggregates of the two-and three-digit Standard Industrial Classification (SIC) codes. For each of these sectors the material provided by RFF gives pollution emissions per dollar of output of each sector in the base year, 1967.

Pollutants were divided into air, water, and solid wastes. Air pollution emissions were divided between emissions from heat and power generation and emissions from industrial processes. Air pollutant emissions factors derived from several sources for coal, gas, and fuel oil were applied to calculate total emissions from heat and power generation for manufacturing sectors, with fuel consumption information being obtained from the Census of Manufacturers (1963). For non-manufacturing sectors, emissions factors were applied to the output base of a particular sector to calculate emissions from heat and power generation. In a similar manner, air pollution emissions coefficients from industrial processes were developed per unit of output. Finally, the combined coefficients for air pollution emissions of both types were provided.

A study by the International Research and Technology Corporation (IR&T), A Model for Strategic Allocation of Water Pollution Abatement Funds,[3] provided a significant portion of the water pollution data for the RFF work. Among the data were included emission factors, urban runoff and waste water loads, and waste water from livestock.

1967 solid waste loads generated by particular sectors were obtained from information included in previous studies, such as one completed by Combustion Engineering, Inc. Solid waste coefficients were developed by dividing waste loads by output bases.

In terms of input-output equations the core model can be shown as:[4]

$$AX+Y=X$$

where X=column vector (185 x 1) of total outputs
Y=column vector (185 x 1) of final demands
A=185 - order matrix of input - output coefficients

and combined to
AX=intermediate demands.

Solving the above equation for X using simple matrix algebra:

$$X = (I - A)^{-1}Y$$

Where $(I - A)^{-1}$ is an inverse matrix denoting the direct and indirect requirements per dollar of final demand.

To complete the schematics of the model a number of exogenous factors were tied to the core model; these factors were subsequently interconnected in various ways. The completed RFF model provided a diagramatic representation of the data, treating interrelationships in a viewable format.

Reference to Figure 2 which depicts this equation in matrix form will help in interpreting this equation. The part of the matrix dealing with interindustry transactions is a representation of the inverse matrix in the above equation. The elements of this inverse matrix indicate the number of dollars of output of each sector (sectoral output) necessary to deliver a dollar's worth of each commodity to final users (sectoral final demand). The adjacent part of the matrix cites the final destination (final demand) of the commodities from various sectors and is categorized by government, investment, and personal consumption expenditures (foreign trade account not listed). The final column lists the total outputs for various industries in terms of dollars.

Attached to the matrix is another component which deals with the pollution emitted by each industry during the production of commodities. In matrix algebra notation, this component[5] can be described as:

$$P = MX$$

where P = column vector (12 x 1) of total pollution
X = column vector (185 x 1) of total outputs from previous equation
M = matrix (12 x 185) of pollution coefficients.

The matrix, M, transforms total output into pollution resulting from industrial production. Since sectoral output is related to sectoral final demands (the dominant share of which stems from personal consumption expenditures), and since pollution generation is related to sectoral output level, a relation exists between final demand and the pollution generated by the economy to satisfy this demand, thus:

$$P = M\ (I - A)^{-1}Y$$

IV.B Production-Consumption Categories

The basic data for consumption expenditures was taken from Expenditures Patterns of the American Family[6] by the National Conference Board in New York (1965). Data from the National Conference Board (NCB) was collected through a survey conducted by the Bureau of Labor Statistics of the U. S. Department of Labor representing average annual family expenditures for the

calendar years 1960 and 1961. The survey is based on a representative cross section of the nation's nonfarm population. "Farm families account for 6% of the nation's population but a smaller proportion of total consumer buying."[7]

The first step in setting up the model reported here was to reconcile the consumption categories found in the National Conference Board data with the Almon product categories[8] in which the "pollution from production" data were given. This basically involved a two-step process: first, determination of the composition of the consumption categories from the National Conference Board; and second, aggregation and disaggregation of the various categories from both sets of data to determine the final consumption-production sectors.[9]

IV.C Consumption Data

After the final consumption-production categories had been organized, the next task was to calculate the consumption patterns by groups. It was decided to use proportions of the family budget spent on each of the ascertained categories, and then to update these proportions to the year 1970, rather than to use the actual dollar figures, in order to more easily circumvent the problem of inflation. In this way, differential inflation in product categories would be reflected in the proportion of the budget spent for the consumer categories; and the actual rate of inflation in the economy as a whole would be reflected in the increased family incomes.

The National Conference Board data on consumption by different groups, was then organized into its appropriate consumption-production category, and charts were then developed to show proportions of the family budget spent for our 48 product categories by different consumption groups (regional, age of head, income) and for the U.S. as a whole for 1960.

IV.D Developing 1970 Proportions

The 1960 data on consumer spending, compiled by the Bureau of Labor Statistics, was the last complete survey which explored differential consumption patterns by the analytical groups which we chose for our study, that is region, age of head, and income. In order to more accurately reflect changes in the consumption patterns of groups, and differential changes in product consumption by the nation as a whole, between 1960 and 1970, a wide range of informational sources were integrated into the updating of proportions to 1970. Since no source of information was available which categorized consumer buying patterns for 1970 by our analytical groups, we chose instead to update the total U.S. consumption patterns with available data and then to apply these changes to the differential consumption patterns by groups. In this way, it was assumed that relative proportions spent by the analytical groups changed in roughly the same way that the total U.S. proportions changed.

The first basic source of updating information came from the Department of Commerce Table 2.5 of National Income and Product Accounts of the United States "Personal Consumption Expenditures (PCE) by Type of Product."[10] The Department of Commerce's PCE expenditure categories were apportioned to coincide with the 48 production-consumption categories. Where Commerce categories were not sufficiently disaggregated, other sources of information were incorporated. These included such sources as FHA, USDA, DOT, National Paper Association, and FDA.

Proportions of expenditures by product category were calculated for 1960 and 1970, and a rate of change within the decade was ascertained.

This rate of increase or decrease was applied to the 48 production-consumption proportions to obtain the new proportions for 1970 for the total U.S. Then this rate of change was applied to the proportions for each analytical group. Each new proportion was re-evaluated over the new sum of the proportions to insure that the proportions for each analytical group added to 1.

Information on number of households and median income for each analytical group was obtained from the Bureau of the Census, General Social and Economic Characteristics, U. S. Summary[11] for 1970 and Current Population Reports,[12] July 1970. The category proportions for each analytical group were then multiplied by the number of households and median income of that group to determine dollar amounts spent by each group for each consumer item in 1970 dollars.

This dollar amount spent for each consumer item by analytical group was multiplied by the pollution coefficient from the RFF data, i.e., pounds of pollutants per million dollars of final product, for each category of consumer item and each type of pollutant to obtain the pollution contribution of each consumer item and each analytical group.

FOOTNOTES

1. Commission on Population Growth and the American Future, Research Reports of the Commission on Population Growth and the American Future, Vol. III, Population, Resources, and the Environment, Ronald G. Ridker, ed. (Washington, D.C.: Government Printing Office, 1972.)

2. See Appendix to this study for comparative lists.

3. Ivars Gutmanis, Leslie Ayers, and Charles Schultze, IR&T, November, 1970.

4. Henry W. Herzog, Jr., and Ronald G. Ridker, "Methodology--The Model," in Commission on Population Growth and the American Future, Research Reports of the Commission on Population Growth and the American Future, Vol. III, Population, Resources, and the Environment, Ronald G. Ridker, ed. (Washington, D.C.: Government Printing Office, 1972), Chapter II.

5. H. Herzog, Personal Communication, Bureau of Business and Economic Research, University of Maryland, College Park, Maryland, July, 1972.

6. National Conference Board, Expenditure Patterns of the American Family, New York, 1965, p. 6.

7. Ibid.

8. Clopper Almon, Jr., The American Economy to 1975 (New York: Harper-Row, 1969.)

9. See Appendix to this study for the forty-eight personal consumption categories and the corresponding sectors in the Clopper Almon and National Conference Board topologies.

10. Department of Commerce. National Income and Product Accounts of the U.S., pp. 44-47.

11. U.S. Bureau of Census. General Social and Economic Characteristics 1970, Summary, September 1972, pp. 1-458-9.

12. U.S. Department of Commerce, Bureau of Census, "Consumer Income," Current Population Reports, Series P-60, No. 70, July 16, 1970.

SECTION V.
POLLUTION DATA

The data on pollution by each of the product categories was obtained for twelve pollutants listed below, and shown in

WATER	AIR	SOLID WASTE
Biological Oxygen Demand	Particulates	Solid Waste
Suspended Solids	Nitrous Oxides	
Dissolved Solids	Carbon Monoxide	
Phosphate Compounds	Hydrocarbons	
Nitrogen	Sulfur Oxides	

Tables 1 - 3. For each of the above pollutant types, the percent of pollution contributed by each of the 10 highest polluting items, and the percent of aggregate consumption expenditures for that item was calculated. Figures for aggregate consumption expenditures were obtained by multiplying average median family incomes by the total number of families for the U.S.

The percent of total pollution figures represents the sum of all pollution which occurs in production of that item until it reaches the consumer. Referring back to the model the pollution index for each item comprises all pollution caused in the extraction of the raw materials, the pollution from all interindustry production of goods and services, and the pollution from final production of each consumer item.

The most important characteristic common to these tables are the two concentration patterns: while these top 10 categories represent 30 to 55% of all consumption expenditures they represent 65 to 95% of all pollution in each category. This implies that efforts to combat pollution can and probably should be concentrated on those few consumer commodities that result in the greatest pollution. In general, agricultural products are the preponderant source of water pollution; utilities, housing, and automobile products are the major contributors to air pollution, and these two together produce the bulk (80%) of the solid waste pollution. (Utilities, housing, and automobiles primarily contribute inorganic solid waste; agricultural products contribute primarily organic solid waste).

Perhaps most notable is the frequency with which certain categories seem to reappear at the top of each pollutant list. These categories, which comprise a list of "top pollutant" items, will be further examined in the next section.

TABLE 1

WATER POLLUTANTS (1970)

	Consumer Items	Percent of Total Pollution	Percent of Aggregate Consumption Expenditures
Biological Oxygen Demand (BOD-54,228 million lbs.)			
(10)*	Meat, Poultry and Eggs	42.6	5.4
(9)	Dairy Products	11.4	2.5
(8)	Apparel	5.4	5.7
(7)	Toiletry Items	4.7	2.7
(6)	Laundry and Cleaning Supplies	3.4	2.0
(5)	Drugs and Medical Equipment	3.3	1.3
(4)	Cereals and Bakery	2.9	2.2
(3)	Fruits and Vegetables	2.6	2.5
(2)	Autos, Parts, and Repair	2.5	8.9
(1)	Sugar and Confections	2.3	.5
		81.0%	33.7%
Suspended Solids (932,282 million lbs.)			
(10)	Meat, Poultry and Eggs	68.5	5.4
(9)	Dairy Products	16.3	2.5
(8)	Fruits and Vegetables	2.4	2.5
(7)	Cereals and Bakery	2.1	2.2
(6)	Household Utilities	1.7	3.9
(5)	Tobacco	1.2	1.2
(4)	Shelter and Other Realty	.9	11.4
(3)	Apparel	.9	5.7
(2)	Autos, Parts, and Repair	.8	8.9
(1)	Sugar and Confections	.6	.5
		95.4%	41.7%
Dissolved Solids (84,179 million lbs.)			
(10)	Toiletry Items	15.8	2.7
(9)	Laundry and Cleaning Supplies	11.4	2.0
(8)	Drugs and Medical Equipment	10.8	1.3
(7)	Apparel	10.3	5.7
(6)	Meat, Poultry and Eggs	5.1	5.4
(5)	Autos, Parts, and Repair	5.1	8.9
(4)	Household Paper Supplies	3.7	.3
(3)	Dairy Products	2.7	2.5
(2)	Medical Services	2.6	5.9
(1)	Insurance	2.6	10.4
		70.1%	45.1%

*Pollution index used to derive aggregate rank scores is discussed in Section 4.0.

TABLE 1 (Cont.)

WATER POLLUTANTS

	Consumer Items	Percent of Total Pollution	Percent of Aggregate Consumption Expenditures
	Phosphate Compounds (8,751 million lbs.)		
(10)	*Meat, Poultry and Eggs	73.6	5.4
(9)	Dairy Products	16.9	2.5
(8)	Fruits and Vegetables	2.1	2.5
(7)	Cereals and Bakery	1.3	2.2
(6)	Medical Services	.9	5.9
(5)	Apparel	.8	5.7
(4)	Tobacco	.5	1.2
(3)	Fats and Oils	.5	.5
(2)	Insurance	.5	10.4
(1)	Autos, Parts, and Repair	.3	8.9
		97.4%	45.2%
	Waste Water (66,344 billion gallons)		
(10)	Meat, Poultry and Eggs	30.1	5.4
(9)	Fruits and Vegetables	20.5	2.5
(8)	Dairy Products	10.4	2.5
(7)	Cereals and Bakery	7.5	2.2
(6)	Fats and Oils	5.4	.5
(5)	Apparel	5.3	5.7
(4)	Tobacco	4.9	1.2
(3)	Sugar and Confections	1.7	.5
(2)	Autos, Parts, and Repair	1.3	8.9
(1)	Alcoholic Beverages	1.1	1.2
		88.2%	30.6%
	Nitrogen (24,436 million lbs.)		
(10)	Meat, Poultry and Eggs	72.9	5.4
(9)	Dairy Products	16.8	2.5
(8)	Fruits and Vegetables	2.4	2.5
(7)	Cereals and Bakery	1.4	2.2
(6)	Medical Services	.9	5.9
(5)	Apparel	.8	5.7
(4)	Tobacco	.7	1.2
(3)	Fats and Oils	.6	.5
(2)	Insurance	.5	10.4
(1)	Autos, Parts, and Repair	.3	8.9
		97.3%	45.2%

*Pollution index used to derive aggregate rank scores is discussed in Section 4.C.

TABLE 2

AIR POLLUTANTS (1970)

	Consumer Items	Percent of Total Pollution	Percent of Aggregate Consumption Expenditures
	Particulates (28,401 million lbs.)		
(10)	*Household Utilities	17.8	3.9
(9)	Autos, Parts, and Repair	10.6	8.9
(8)	Meat, Poultry and Eggs	7.0	5.4
(7)	Apparel	5.6	5.7
(6)	Toiletry Items	4.3	2.7
(5)	Dairy Products	3.9	2.5
(4)	Shelter and Other Realty	3.8	11.4
(3)	Insurance	3.7	10.4
(2)	Cereals and Bakery	3.4	2.2
(1)	Laundry and Cleaning Supplies	3.1	2.0
		63.2%	55.1%
	Nitrous Oxides (11,171 million lbs.)		
(10)	Household Utilities	41.7	3.9
(9)	Autos, Parts, and Repair	7.2	8.9
(8)	Insurance	5.2	10.4
(7)	Apparel	4.6	5.7
(6)	Meat, Poultry and Eggs	3.8	5.4
(5)	Shelter and Other Realty	3.1	11.4
(4)	Toiletry Items	3.0	2.7
(3)	Medical Services	2.5	5.9
(2)	Footwear and Accessories	2.2	1.8
(1)	Laundry and Cleaning Supplies	2.2	2.0
		75.5%	58.1%
	Carbon Monoxide (9,231 million lbs.)		
(10)	Autos, Parts, and Repair	33.7	8.9
(9)	Shelter and Other Realty	16.7	11.4
(8)	Meat, Poultry and Eggs	3.9	5.4
(7)	Toiletry Items	3.7	2.7
(6)	Household Paper Supplies	3.3	.3
(5)	Apparel	3.1	5.7
(4)	Insurance	3.0	10.4
(3)	Newspapers	2.8	.5
(2)	Laundry and Cleaning Supplies	2.6	2.0
(1)	Dairy Products	2.5	2.5
		75.3%	49.8%

*Pollution index used to derive aggregate rank scores is discussed in Section 4.0.

TABLE 2 (cont.)

AIR POLLUTANTS (1970)

	Consumer Items	Percent of Total Pollution	Percent of Aggregate Consumption Expenditures
	Hydrocarbons (17,620 million lbs.)		
(10)	* Autos, Parts, and Repair	30.4	8.9
(9)	Shelter and Other Realty	14.7	11.4
(8)	Meat, Poultry and Eggs	7.0	5.4
(7)	Apparel	5.4	5.7
(6)	Insurance	3.8	10.4
(5)	Dairy Products	2.9	2.5
(4)	Toiletry Items	2.9	2.7
(3)	Fruits and Vegetables	2.9	2.5
(2)	Cereals and Bakery	2.6	2.2
(1)	Medical Services	2.3	5.9
		74.9%	57.6%
	Sulfur Oxides (76,922 million lbs.)		
(10)	Apparel	26.2	5.7
(9)	Household Utilities	25.6	3.9
(8)	Autos, Parts, and Repair	9.5	8.9
(7)	Shelter and Other Realty	3.7	11.4
(6)	Insurance	3.3	10.4
(5)	Floor Coverings	3.2	.3
(4)	Household Textiles	2.8	.5
(3)	Meat, Poultry and Eggs	2.5	5.4
(2)	Footwear and Accessories	1.9	1.8
(1)	Recreational Transportation	1.7	1.8
		80.4%	50.1%

TABLE 3.3

SOLID WASTE (1970)

	Consumer Items	Percent of Total Pollution	Percent of Aggregate Consumption Expenditures
(10)	Meat, Poultry and Eggs	31.0	5.4
(9)	Autos, Parts, and Repair	17.8	8.9
(8)	Shelter and Other Realty	9.1	11.4
(7)	Dairy Products	8.3	2.5
(6)	Household Utilities	7.1	3.9
(5)	Fruits and Vegetables	5.7	2.5
(4)	Cereals and Bakery	2.7	2.2
(3)	Apparel	2.0	5.7
(2)	Tobacco	1.7	1.2
(1)	Fats and Oils	1.5	.5
		86.8%	44.2%

*Pollution index used to derive aggregate rank scores is discussed in Section 4.0.

SECTION VI
CONSUMER POLLUTANTS

In the preceding tables it is apparent that many categories re-appear consistently among the top 10 for each pollutant type. In order to specify more precisely both the frequency and position of occurance in these 10 top categories, the summed ranks for all 12 pollutants were used to derive an aggregate pollution index for each consumer category. The rank ordering was found to be:

Name	Score *
Meat Poultry and Eggs	99
Apparel	72
Autos, Parts, and Repair	68
Dairy Products	65
Shelter, and Other Realty	46
Fruits and Vegetables	44
Household Utilities	41
Cereals and Bakery	40
Toiletry Items	38
Insurance	32
Laundry and Cleaning Supplies	19
Tobacco	19
Medical Services	18
Drugs and Medical Equipment	13
Fats and Oils	13
Household Paper	10
Sugar and Confections	5
Floor Coverings	5
Household Textiles	4
Footwear and Accessories	4
Newspapers	3
Alcoholic Beverages	1
Recreational Transportation	1

These categories, then, can be looked at as contributing a major portion of pollution in the U.S. economy. Thus, consumption patterns for these items become the focal point in any discussion of reducing pollution by reduction of consumption of highly polluting items.

Consumption patterns for three main classifications will be examined: income, age-of-head of household, and region of the U.S. These classifications for analysis of consumption patterns were chosen as indicators of the major differential consumer groups in the U.S. society. An analysis of these three sets of consumer groups will indicate the differential consumer patterns which influence market decisions, and thus

*Scores were obtained by summing ranks shown in Tables 3.1-3.3 (the maximum possible score is 120).

differential methods of reducing pollution by affecting consumption patterns. In the analysis of the three groups which follows, it became apparent that only two of the groups--income and age-of-head of household--revealed major differences which were important indicators of buying habits which could be affected by policy decisions. Regional differences revealed no significant differences which were not accounted for in the analysis of the two other groups.

Figure 3 looks at pollution contributed by each income group for each of these 10 highest polluting items. It is obvious that the two highest income groups (which together include persons who earn over $10,000 per year) by their consumption of these ten items, over-contribute to the pollution problem. These two groups, comprising only 44% of the population, contribute an average 65% of the total pollution for these 10 items. The two lowest income groups, (which together include those who earn under $5000 per year) representing 29% of the population, contribute approximately 10% of the pollution. With respect to consumer items it is apparent that the lowest income groups contribute heavily to food and shelter items; the items in which the highest income groups contribute most are insurance, apparel, autos and toiletries--more apparent luxury items.

Figure 4 examines pollution contribution for each consumer item by age-of-head of household. Looking at the graph of average aggregate expenditures, it appears that the groups with age-of-head of household 25-54 "over-consume" compared to their relative size in the population. Especially high are the groups from age 35-54 which comprise 38% of the population but average 49% of the aggregate consumption expenditures and therefore 49% of the pollution contribution. The group with age-of-head of household 55-64 contributes an average 17% of the consumption expenditures and is 17% of the population. The two extreme groups, with heads of household under 25 and over 65, both "under-consume" relative to their size in the population. The over 65 age group is especially notable, as it comprises 19% of the population but averages only 7% of the aggregate consumption expenditures. The highest proportional expenditures for this over 65 group, are in food and shelter commodities, while the highest proportional expenditures for age groups 35-54 are in apparel, insurance, and toiletries. Thus, if a reduction in pollution is desired through a reduction in consumption expenditures, it seems obvious that attention should be focused on those groups who consume most heavily, that is, households in which the age-of-head of household is 25-54.

Figure 5 compares regional consumption expenditure differences (see Appendix for map of regional divisions). Relative to their proportions in the population, the Northeast and Northcentral regions over-consume. Comprising 24 and 27% of the population respectively, they contribute 27 and 29% of the consumption expenditures, and therefore of the pollution.

SECTION VII
PERSONAL CONSUMPTION ITEMS

The purpose of the consumption model of pollution generation is to assign responsibility for pollution both to decision makers in production, and to consumers who demand the final products. Viewed from this perspective, there are essentially two ways in which to lower pollution: 1) to make changes in production methods or materials; and 2) alter consumption patterns. The following section will deal with consumption patterns of the ten highest polluting categories of personal consumption goods, and some of the issues involved in making changes in consumption patterns.

The ten categories of personal consumption items fall into two basic consumption patterns. Meat, Poultry, and Eggs; Dairy Products, Fruits and Vegetables, Cereals and Bakery, Toiletry items, Household Utilities, and Shelter and Other Realty constitute the first consumption pattern group, and Auto Parts and Repair, Apparel and Insurance, the second. Each of these consumption pattern groups will be examined [see Figures 6-10] according to consumption patterns which emerge for income and age-of-head of household groups.

Of the ten top ranking categories of personal consumption items scored in Section 4.0, four of them are foods: 1) meat, poultry and eggs, 2) dairy products, 3) fruits and vegetables and 4) cereals and bakery. The consumption patterns for all four categories of these personal consumption goods are similar. As income rises, the average dollars spent per household per year for these food categories increases. However, as income increases, the average proportion of the household budget spent on each food category decreases. Personal food consumption tends to be relatively inelastic in terms of quantity (calories) an individual consumes. The relative inelasticity would account for the proportionate decrease. Thus it appears that increases in expenditures for food reflects the buying of better quality foods which tend to be more expensive. This does not discount the probability of an increase in quantity food buying, though this would appear to be slight. As will be noted below, this increase in quantity buying will often be due to increased size of the family unit, which shows a high correlation with an increase in income. Thus the key issue raised in this respect is whether quality food products which generally demand higher prices are more polluting than food products of lesser quality of lesser expense. Determination of this issue will be essential to any wise decision in regard to alteration in consumption patterns of food products.

For the four food consumption categories, by age-of-head of household, average dollars spent per household per year is less for groups with the age-of-head of household under 25

and over 65, with the maximum amount being spent by the group with age of head 35-44. The proportion of the household budget is similar for all age groups, with a slight increase noted in the 65 and over age group. These consumption patterns basically reflect normal increase in family size and its decrease as the family grows up. Heads of households under 25 years old or over 65 reflect the times in life when families are just beginning to grow or after the children have left their families leaving parents alone. The 35-44 age groups of heads of households is the time when persons find their maximum number of children at home. This appears to account for most of the expenditure patterns by age of household.

Both the age-of-head of household and the income level consumption patterns for the four food categories reflect no excessive over-consumption by any group. The foods in these four personal consumption categories are considered basic necessities, of which consumption cannot be cut below a certain point without affecting health. It would appear that changes in production methods and materials will be the more effective way of dealing with pollution from the food categories than trying to alter their consumption patterns.

The consumption patterns for toiletries are similar to the patterns for the food categories. As income increases, total dollars spent on toiletries increases, and the proportion of total budget decreases, but at a lesser rate than on the decrease noted on food categories. These patterns are consistent in regard to demand changes because of family size increase and quality, as has been explained in previous paragraphs. However, it appears that the demand curves for toiletries is relatively elastic thus indicating much of toiletries consumption is not of an "essential" type. Such would indicate that alteration of consumption patterns in this category would be an effective means of pollution reduction.

The third major category in the first consumption pattern group is shelter categories which include: 1) shelter and other realty and 2) home utilities. As with the four food categories, as income increases, the average dollars spent increases, and the proportion of the total family budget spent on shelter and utilities decreases. But this proportional decrease falls at a faster rate than food categories, and the dollars spent increases at a slightly faster rate. The consumer groups with age-of-head of household between 25-64 spend the highest dollar amounts and the lowest proportion of household budget on shelter. Only the under 25 age-of-head of household group spends a lower proportion on home utilities. There does exist, as noted before, a high correlation with age-of-head of household, income level and family size. Responsibility for increased family size and increasing income level as age increases reflects a consistent expenditure pattern in the shelter categories.

However, expenditures for housing has a relatively elastic demand curve. Thus, although increases in family size significantly effect housing expenditures, it seems apparent that, as income increases, persons tend to buy more expensive and better quality homes. Life styles emphasizing nice things may influence much of the increase in expenditures for quality housing but, undoubtedly, present tax laws in regard to interest and depreciation deduction account for much of the motivation to increase an individual expenditure in shelter categories. To alter consumption patterns in shelter categories some changes in tax laws will be necessary. An issue which must be resolved is the relative amount of pollution the production of an expensive home results in, versus cheaper housing. A problem comes forth in this regard in that the price of the land may be a greater influence on a home's value than the structure itself. Another issue is what constitutes over-consumption in shelter? The rapid rise in dollars spent on shelter and utilities would seem to indicate that, while consumption cannot be cut below a certain minimal point, there is room for a lowering of consumption of the highest income groups and middle age-of-head of household groups, while allowing them to maintain some degree of higher spending and greater comfort.

There are three other personal consumption categories which must be discussed. These are apparel, autos and insurance. These products will be discussed separately for two reasons. First, they are generally non-necessity items, and second, their consumption patterns are such that they are more susceptible to changes which would lower pollution.

Two of these three consumption categories which have similar consumption patterns are apparel and insurance. The average dollars spent per household in the categories increases at an extremely rapid rate as income increases. As income increases, the proportion of the household budget spent on apparel also increases. The total dollars spent on the categories is the highest for the age groups 25-54 and these three age groups also spend the highest relative proportions of their budget on apparel and insurance. The over 65 age group spends much less proportionally and in actual dollars on insurance and apparel. The patterns for income and age of head of household are consistent because of the high correlation between the two. Though at some minimal level the demand curve for apparel may be inelastic, the demand curve above this minimum is relatively elastic. Thus, it seems clear that increases in both quantity and quality of apparel take place as income level increases. No doubt much could be done to alter consumption patterns in apparel to reduce pollution (if such is deemed desirable); however, the real issue is which varieties of fabrics actually result in greater pollution. For example, does growing cotton, which requires fertilizer and pesticides, cause more damage than manufacturing synthetic materials which uses many chemicals?

Families tend to purchase more expensive homes and more automobiles (i.e., second cars) as their income levels rise. To provide for family security and prevent possible financial ruin in case of an accident, one insures his house, automobiles and life. The more valuable one's home or cars, the more insurance is paid; and the higher one's income level, the higher one's price for insurance. This also increases with age. Though these consumption patterns could be altered easily, some other method of providing financial security would have to be devised if that alteration is to be acceptable.

The final consumption category of importance is auto purchase, parts, and repairs. The proportion of a budget spent on autos increases through income levels $500-7500 and remains fairly constant until income groups over $15,000, where the proportion decreases. Total dollars spent on autos by age-of-head of household is highest for age groups 25-54. Proportion of budget spent on autos is highest for those under 25 with the proportion decreasing as age increases. The young who are just beginning to earn their livlihood have lower median incomes than those in the prime years of employment. The youngest age groups have greater desires for mobility (especially compared to the over 65 age groups) and thus are willing to spend a much greater proportion of their budget on auto purchases. Data reveal that the number of autos owned increases as income increases. This raises the issue of whether two or three cars per household constitute over-consumption. Another issue in regard to automobiles consumption is whether the cheaper or more expensive cars are the greatest polluters. Factors involved in this determination are quantity of parts in the auto, processes used to make the parts, efficiency of its engines and amount of energy consumed. However, it is clear that alteration of auto consumption could have a noticeable effect on pollution reduction.

Whether some mechanism should be sought to alter personal consumption patterns to aid in the reduction of pollution is a personal decision to change one's life style or a governmental policy decision. This analysis has sought to provide some understanding of where the consumption patterns affect the pollution in the nation. It seems clear that products contributing the greatest pollution are those which are essential to health. Thus any change in consumption patterns will have to take place among specific food substitutes rather than between food categories. Other high polluting products reflect personal desire for comfort and economic security. To alter consumption patterns these areas should be somewhat easier than in essential food categories but nevertheless will be difficult even if deemed to be desirable because adequate substitutes must be provided.

A note should be made in regard to the significance of over-consumption by the higher income levels. Because these income levels are so small in relationship to the massive middle class that, for policy making, little consideration should be given to the consumption levels of very high or

very low income groups. It is the consumption patterns of America's middle class that has the greatest effect with respect to pollution. National policy must look at the forces causing this if we are to use alteration of consumption patterns as a tool to bring about a reduction in pollution.

There are three important limitations which must be considered in this type of consumption-pollution analysis. The first is the masking of highly polluting industries. By the nature of the input-output analysis which was used to determine the pollution caused in the total process of production of final consumer goods, some of the most highly polluting industries did not appear on the final list of the top ten polluting categories primarily because a good portion of their production was inter-industry production. Thus, the pollution which these industries caused was distributed over those consumer items to which they contributed. Examples of this can be seen in the paper, auto, or electrical energy generating industries. Although each of these industries contributes heavily to the pollution problem in the U.S., the products which they produce for the final consumer is a small part of their total output. A major portion of their output is delivered to other industrial producers, and it is to these final producers that the pollution is allocated. This becomes especially important for the policy maker, who is trying to determine possible trade-offs in consumer items, and who must recognize all contributing factors to pollution of any of the possible substitute items.

The second limitation deals with imports and exports. By the nature of the data used to develop the pollution figures, all pollution which was generated in the United States, and only that pollution is included. In terms of our model this means that all pollution which was caused in the production of goods (subsequently exported from the U.S.), is still included in our model, and was distributed over the total amount of goods purchased in the U.S. On some items, which were heavily exported, this would mean that the pollution caused per dollar of item bought was higher than it should have been. On the other hand, the pollution caused in production of goods made outside the U.S., then imported and sold in the U.S., is not included in the model. For the purposes of this report, the assumption was made that these two amounts of pollution balanced out. Testing the validity of this assumption was beyond the scope of this project. It is, however, an area which should be considered in any further investigation.

The final area of concern, deals with the spatial distribution of pollution. One of the most important variables in pollution severity is the concentration or dispersion of pollution sources. If the pollution is dispersed over wide areas the natural ecological system can deal with the pollution naturally without undue harm. Pollution problems are amplified by the concentration of pollution in small spatial areas, where problems of interaction of

pollutants, as well as the mere concentration of the pollutants, puts great strains on the environment. The data which were used in preparing this report did not allow us to deal with the problems of spatial distribution of pollution, but only with total amounts of pollutant which were put into the environment by various industrial processes. It is well to be aware, that while the total amount of pollution contributed by various consumer items is extremely important, the policy maker must be aware of the spatial distributions which come into play.

SECTION VIII

REQUIRED WORK ON CONSUMER PRODUCT USAGE

The second major component of the consumption model is that of usage of the product by the consumer. A brief investigation of these areas of consumer product usage-- water, electrical energy and transportation-- indicated that the magnitude of the effort required to adequately evaluate pollution impact of consumer product usage was not within the capability of our research due to time and resource limitations, as well as difficulty of obtaining readily available pertinent data. However, a number of generalizations developed from our brief investigations, which, though not adequately supported by thorough research, should be noted as areas which need further substantiation by empirical research.

It does not appear that residential and household water consumption contributes significantly to pollution. Water, however, is a primary carrier of pollutants, and a few household polluting agents are carried away from the home by water. Chief among these are residues of laundry detergents, (primarily phosphates), and suspended solids and organic matter from home food waste disposals. Water delivery systems, water-using appliances and waste water disposal systems add to pollution by their consumption of electricity. Variations exist among socio-economic classes due to the higher income groups' possession of more water, and waste water disposal using appliances. However, regional variations are not significant with respect to pollution impact.[1]

Almost every home in the United States is wired for electrical energy use. Electrical energy, at the point of household consumption is non-polluting but at the site of generation, (by fossil-fuel fired power plants), it results in significant amounts of pollution. In the United States in 1970, 81% of electrical power was generated by the burning of fossil fuel.[2]

The residential sector in 1970 consumed approximately 25% of the total electrical energy consumed in the United States.[3] Space heating, water heating, cooking, and refrigeration account for more than 80% of the residential usage. Space heating is the foremost user of electrical energy, consuming over 50% of residential electricity used.[4]

A number of factors appear to affect regional variations in the pollution impact of electrical energy generation. First is the population density. The number of units using electricity is a function of this density. The second is climate, which is reflected in the high concentration of air conditioners in warmer regions of the nations and the greater use of heating systems in colder regions. A third factor is the type of energy use to generate electricity in the area. In the Northeast and Northcentral regions, where much high sulphur content coal is used, pollution is generally greater, particularly sulphur pollution. In the West, much of the electricity is generated by hydro-electric plants; thus,

little air pollution occurs. In addition, low-sulphur coal is available in the West; thus, air pollution from coal-fired power plants is relatively less than in other areas.

A limited amount of reliable data is available on ownership and use of both water-using and electricity-consuming appliances by various socio-economic classes. There are, however, indications that significant variations exist among income groups in regard to ownership of household appliances even though refrigerators and television sets are found in nearly all of the homes in the United States.[5]

The primary energy source of the transportation systems in the United States is fossil fuels. The combustion of fossil fuels result in emission of pollutants directly from the exhaust systems of the motor vehicles and airplanes. Some pollution results from electrical energy consumed by subways, and elevated and surface commuter trains.

It is apparent that income levels have a significant effect on the type of transport system people use. One major factor is the high cost of personal automobiles and the relatively expensive fares of some transportation systems in comparison with others. Indications are that ownership of an automobile (and number of automobiles owned) increases with income level.[6] This affects the total miles traveled by a household and thus influences pollution contribution of that family. Also, it appears that bus travel decreases and airplane travel increases as income level increases. This is no doubt due to low income groups being unable to afford expensive airline fares and the expense of traveling long distances. Social variations also exist, presumably because a high correlation exists between income level and occupation and education. However, regional variations in pollution attributed to using transportation systems can also be accounted for by its high correlation with population density in the area.

There are other important factors which must be analyzed to understand the impact of the use of transportation systems by socio-economic classes. Among these are percentages of pollutants by weight emitted by each type of transport, number of passengers carried per transport unit, and person-miles traveled in each type of transport.

The solid waste component of the consumption model constitutes the final stage of product flow from raw material growth (or extraction) to disposal. Solid waste generated in the industrial and agricultural production of consumer items has been taken into consideration in the production component of the model. The remaining part of the solid waste component to be treated is the solid waste generated by the residential sector. A survey of available literature in the area of differential residential generation of solid waste reveals that only a very limited amount of pertinent research has been compiled; as a result, no national generalizations could be drawn. However, a regional study of the

quality and quantity of residential solid waste generation, which was in progress at the time of printing this report, should provide some much needed data.

FOOTNOTES

1. F.P. Linaweaver, Jr., John C. Geyer, and Jerome B. Wolff, Final and Summary Report on the Residential Water Use Research Project, Report V on Phase Two of the Residential Water Use Research Project. (The project was conducted during the period from October 1961 to June 1966 by the John Hopkins University under the Technical Studies Program of the Federal Housing Administration in cooperation with sixteen participating water utilities located throughout the United States) June, 1966.

2. Electrical Energy Association (EEA), The Comparative Environmental Impact in 1980 of Fossil Fuel Space Heating Systems Versus Electric Space Heating, Figure 2.8, pp. II-20, (Prepared by Gordian Associates, Inc., N.Y., N.Y.) March, 1972.

3. Federal Power Commission (FPC), The 1970 National Power Survey--Part I, Table 1.1, "Categories of Electric Power Use--1965-1970-1990," p. I-1-3 (U.S. Government Printing Office, Washington, D.C.) December, 1971.

4. Stanford Research Institute (SRI), Patterns of Energy Consumption in the United States, p. 33, (A Report Prepared for the Energy Policy Staff, Office of Science and Technology, Office of the President, Washington, D.C.) Menlo Park, California, January, 1972.

5. Bureau of Census, Consumer Buying Indicators, Household Ownership and Availability of Cars, Homes, and Selected Household Durables and Annual Expenditures on Cars and Other Durables: 1971, Department of Commerce Publication, Series-P-65, No. 40, May 1972.

6. George Katona, Lewis Mandell, and Jay Schmiedeskamp, 1970 Survey of Consumer Finances (Ann Arbor: Braun-Brumfield, Inc., 1971) p. 68. The real numbers for the total of each breakdown of the survey for Table 4-7, p. 68, were obtained from Jay Schiedeskamp in a phone conversation. These were used to arrive at the percentages for the income groups used throughout this report.

SECTION IX.
A THEORETICAL INPUT-OUTPUT MODEL FOR HOUSEHOLD CONSUMPTION

A consumptive model of the U.S. economy and its resultant pollution addresses itself to a fundamental concern. It attempts to shed some light on the causes of pollution by uniquely looking at household consumption and the causal chain of the flow of raw materials to eventual solid waste pollution. In this chain the consumer plays the earlier critical role in his exercise of demand for a seemingly ever-expanding supply of consumer products. Consumer demand, then, suggests an innovative area of environmental inquiry as well as a hint of irresponsible and contributory performance to the pollution problem.

Moreover, another suggestion that surfaces during this causal chain of consumer demand-raw material-final product-consumer usage-waste and disposal is that national energy resources as well as raw material resources are being consumed by this consumer decision. Not only are the questions of "what does the consumer buy" and "how does he dispose of it" important, but also how and to what extent does energy service it during its useful life. Indeed, pollution can be viewed from a multivaried perspective of consumer demand.

IX.A Purpose of Model

The purpose of a theoretical input-output model for household consumption is to suggest a methodology to assess differential pollutants and their sources. Through an approach to quantification and subsequent measurement the effects of household pollution can be traced from consumer buying patterns through product utilization habits and their accompanying energy usages to the eventual waste or disposal of the products consumed.

In attempting to set up a consumptive model of pollution, it was found that information on one essential component of the model, i.e., differential usage of products, was unavailable. In setting up a "consumptive" model these data play an important, if not essential part in understanding the consumers role in pollution generation, both industrially and personally.

IX.B Model Description

A theoretical input-output model (as shown in Table 4 for household consumption would address the causal chain of consumer demand-raw material-final product-consumer usage-waste and disposal. In our conceptual model, consumer demand and raw material utilization result in a final product which is purchased or otherwise obtained by the household. This series of activities can be viewed as the input into the household consumption model and constitute the initial household decision. Their basic parameters are products purchased and household profiles. Questions on product purchases attempt to seek data for:

TABLE 4

CONCEPTUAL INPUT-OUTPUT MODEL FOR HOUSEHOLD CONSUMPTION

INPUT	OUTPUT		
Household Parameters	Household Acquisition Of Product	Impact Dimensions	
		During Usage	After Usage
Income Levels	Frequency of Purchase	Efficiency of Product	Quantity of Solid Waste
Age Levels	Quantity of Purchase	Method or Type Of Usage	Nature of Materials To Be Disposed • Biodegradable • Non-biodegradable
Regional Locales	Quality of Products Purchased	Completeness of Usage	Method of Disposal
	Nature of Products Purchased	Frequency and Duration of Usage	Recyclability of Product Materials
		Repair and Upkeep of Product	
		Energy Consumption of Product • Type • Quantity	

- nature of products purchased
- quantity of products purchased
- quality of products purchased
- frequency of purchase

Household profile information qualifies or conditions the product-purchase picture as it seeks data on household composition by:

- income levels
- age levels
- regional locales

Presumably, a differential picture begins to emerge. That is, different groups buy different products in different quantities in different sections of the country, at different times, etc. For example, it would answer such questions as which income groups purchase the highest quality TV sets, how many do they purchase, and how often? This information would be tied in with information on differential pollution by types or brands purchased and from this would begin to develop differential consumption-pollution patterns by groups.

Subsequently, there is an output or a series of impact dimensions that arise as a result of the initial household decision. These impact dimensions are activities that basically occur (1) during usage and (2) after usage.

The "during usage" stage incorporates both performance stage and the energy consumption stage. Basically, how long and how effective is the product being utilized and what energy is being expended to keep it in operation? Product utility questions seek the following information:

- efficiency of product
- type or method of usage
- completeness of usage
- frequency and duration of usage
- repair and upkeep of product
- energy consumption of product (by type and quantity of energy)

These impact dimensions would begin to qualify the earlier basic product-and-household data. For example, it could be hypothesized that poorer people contribute more to pollution by purchasing lower cost (and quality) TV sets, because:

- companies producing TV sets at minimal cost may use more polluting production methods to minimize costs;
- efficiency of the TV set may be poor, thus demanding higher quantities of electrical energy to operate;
- quality of the set may be poor, requiring more frequent and extensive repair or upkeep, thus demanding more production of replacement parts.

The second and last impact dimension would deal with the product or its wastage after usage. This data search would presumably convey back the information of actual pollution:

- quantity of solid waste
- nature of materials to be disposed (biodegradable or non-biodegradable)
- method of disposal (home incineration; sewer system, garbage disposal, public garbage collection)
- recyclability of product materials

Again, this information would begin to assess differential pollution in the sense that, even though lower income groups may purchase fewer TV sets, on the whole they may contribute more to solid waste because the quality of the product they purchase may force them to dispose of it more quickly with less use. On the other hand, this data analysis would bring in the added dimension of second-hand products. That is, while the higher income classes may contribute to less solid waste pollution directly from disposal of heavy appliances because they are re-sold to lower income groups, they are in some sense responsible for the solid waste created after final usage and disposal.

This informational dimension would also help to indicate differences in disposal methods, e.g., garbage disposals vs. garbage collection for food wastes, and differences in product material composition in products purchased by groups which would contribute to easier recyclability into the industrial or total environmental system.

Very closely connected with this information, would be a computer simulation of tradeoff implications in consumption items. This would include evaluation of probable or possible tradeoffs in consumer items (necessitating a much more complete breakdown of consumption category), differential pollution generation in production of tradeoff items (or tradeoff materials), diffusion or concentration of sources of pollution, and differential possibilities of affecting these tradeoffs among consumer groups.

Again, findings of these two studies would presumably either substantiate or obviate the initial household purchase decision, if this would be judged to be a valuable objective for policy study.

SECTION X
APPENDIX

Derivation of Consumption-Production Categories

The consumption data from the National Conference Board divided final consumption items into eight general categories of consumption. Each in turn, is broken down into very detailed expenditures for each group, e.g., food, beverages and tobacco is broken down into 196 categories, sufficiently detailed to allow reaggregation into new categories of consumption consistent with the final demand categories from the model.

Out of the 185 Almon production sectors, 126 are classified as final consumption sectors. Each of these 126 sectors is described by the SIC numbers which apply to that sector. Thus the first step in determining the composition of each sector was to obtain a detailed description of the products which came from industries described, and to develop a list of those products from each sector which would go to final consumption and those which were interindustry products. At this point, a comparison of the product usage descriptions was made with the consumption categories from the NCB and an initial definition of our production-consumption sectors was made, keeping in mind the desirability of maintaining as many consumption categories as possible in order to explore more carefully the differential consumption patterns of income, age, and regional groups, and also keeping in mind the fact that categories must be aggregate enough to satisfy definitions of inclusions in each final demand and consumption sector. On the basis of this information an original classification of sectors by product usage was made in conjunction with consumption categories from the National Conference Board and sectors which were not easily classified were noted for further consideration.

The sectors which could not easily be classified after this primary assessment fell into two general categories. First, sectors whose final "consumption" products were not immediately apparent and secondly, sectors in which final products fell clearly into two or more different consumtive sectors. In solving these problems, two basic sources of information were used:

1. A list of five digit SIC product shipments adjusted for exports and imports for 1958 to 1969 were made available from Bureau of Business and Economic Research at the University of Maryland. This list gives millions of dollars of products shipped from each 5-digit SIC code industry for 1967 and a coefficient which gives the proportion of that shipment which went to personal consumption expenditures.[1]
2. A list of "Industrial Composition of Personal Consumption by PCE Category, in Producers' and Purchaser's Prices, 1963,"[2] published by the U.S. Depart-

ment of Commerce, Office of Business Economics. This gives the final consumption items which are delivered from each industry to personal consumption (classified by the industry classification used in the 1963 Input-Output Study of the Survey of Current Business).

To determine the final "consumption" from problem sectors, a description of each sector by 5-digit SIC code was made. In sectors where final products fell into two or more different consumptive categories, the 5-digit classification was sufficient to divide the sector into its various final consumptive components. Then using the list of product shipments by 5-digit SIC code, the sectors were divided by the proportion of the various consumptive sectors. Two general types of solutions were made. First, some sectors of the product categories contained items which could be classified into two consumptive sectors, e.g., miscellaneous housewares and linoleum, which would be classified under the consumptive sector labeled floor coverings. The five digit SIC codes were sufficiently detailed to allow linoleum production to be removed from the other products. The personal consumption expenditures for linoleum (a multiplicative product of the 1967 product shipments and the proportion of those shipments which went to personal consumption) were divided by the total personal consumption expenditures for the entire sector to determine the proportion of that sector which as to be attributed to miscellaneous housewares and the proportion which was to be attributed to linoleum.

The second type of solution followed the same procedure, however when the personal consumption expenditures were calculated, it was discovered that one of the sectors which required separation was, in fact, void of personal consumption expenditures. That is, part of the sector was producting entirely for other interindustry trades. An example of this was found in the ship and boat repair industry. In trying to separate ship repair (which would be placed in a consumptive sector for long distance ship travel) from boat repair (which would be placed in a sector for other recreational travel), it was found that the SIC sectors which produced for the ship industry had coefficients of zero for the personal consumption expenditures. Thus the final consumption expenditures for this sector were placed entirely in the production-consumption category for other transportation, since ship repair was not a final consumption item for the sector.

A final type of problem presented itself in the product category labeled "Broad and Narrow Fabrics." In this sector, the 5-digit SIC codes did not sufficiently divide the industry to allow separation of the final products into fabrics for apparel and household textiles. The "Industrial Composition of Personal Consumption Expenditures" data allowed separation of fabric for apparel from household textiles, by separating respective purchases for apparel from durable and semi-durable

housefurnishings, which were thus calculated for sectors of the industry which were delivered to apparel and those delivered to household textiles.

It is necessary at this point to make clear the assumption which was used in dividing Almon's product categories into their component consumption parts. The assumption is that within each product category pollution is created equally. That is, if a sector is to be divided into different consumptive parts, it is assumed that the proportion of dollars of final product sold to the consumer is equal to the proportion of pollution created by that part of the sector. Due to time and resource limitations, it is impossible to test the validity of this assumption.

A. Food

1. Cereals and Bakery Products (2)

   a. Grain - 5
   b. Grain Mill Products - 26
   c. Bakery Products - 27

2. Meat, Poultry and Eggs (29, 122)

   a. Poultry and eggs - 2
   b. Meat, animals and livestock, beef and hog farms - 3
   c. Meat products - 23

3. Fish and Seafood (44)

   a. Fish and shellfish - 8
   b. Canned and frozen fish - 25 12%

4. Dairy Products (49)

   a. Dairy farm products - 1
   b. Dairy products, cream and cheese - 24

5. Fruits and Vegetables (63, 133, 174)

   a. Fruits, vegetables and other crops - 7
   b. Canned and frozen fruits and vegetables - 25 88%

6. Fats and Oils (123)

   a. Fats and oils - 32

7. Sugar and Confectionary (154)

   a. Sugar - 28
   b. Confectionary products - 29

8. Misc. Foods (140, 147, 178)

   a. Pasta, spices - 33 61%

9. Beverages (163)

   a. Soft drinks and flavorings - 31
   b. Coffee - 33 39%

B. Alcoholic Beverages

10. Alcoholic Beverages (186)

   a. Alcoholic beverages - 30

KEY TO LISTING

A to M = Major Consumption-Production breakouts.

1 to 48 = Consumption-Production categories used in this report, based on the National Conference Board's sectors identified in parentheses: eg: (2).

a,b,c,etc. = Equivalent Clopper Almon sectors actually used in the Consumption - Production Model which generated the results reported in this document.

C. Tobacco

11. Tobacco Products (192)

a. Tobacco Products - 34

D. Household Operations

12. Shelter and Other Real Estate (3, 7, 22)

a. Sand and gravel, asphalt, clay ceramic -16
b. Cabinets, windows, doors, trim - 43
c. Paints - 68
d. Roofing and painting materials - 69
e. Glass - 78
f. Cement, concrete, gypsum - 81
g. Other stone and clay products - 82
h. Nails and other steel - 83
i. Aluminum - 87
j. Wire - 90
k. Plumbing and heating equipment - 94
l. Structural metal, i.e., doors, platework, ornamental - 95
m. Screws, bolts - 96
n. Credit agencies, banking, brokers - 165
o. Owner occupied dwellings - 167
p. Real Estate - 168
q. Landscaping - 10
r. Metal stampings - 97
s. Machine tools, dyes - 106, 108
t. Gum and wood chemicals - 61 108

13. Fuel, light, refrigeration and water (24)

a. Coal - 14
b. Electric utilities - 160
c. Natural gas - 161
d. Water and sewer services 162
e. State and local electric utilities - 180

14. Lodging outside of home (15, 21)

a. Hotels and lodging places, trailer parks - 169

15. Telephone and other call communication (35)

a. Telephone and telegraph, radio and TV transmitting - 127
b. Call communication - 158

16. Laundry and Cleaning Supplies (39, 40, 42, 168)

a. Soaps, detergents - 67 49%

17. Paper Supplies (41)

a. Converted paper products, paperboard - 48
b. Envelopes, tissues and napkins - 49
c. Paperboard containers - 51

18. Writing Supplies, Cards, and Stationary (49)

a. Pens, pencils, and other office supplies - 149

19. Moving, Freight forwarding, and Storage (48)

a. Freight forwarding - 157
b. Trucking - 153

20. Sprays, and Fertilizers (51)

a. Agricultural chemicals - 61 90%
b. Agricultural fertilizers and chemicals - 59
c. Pesticides and disinfectants - 60
d. Chemical fertilizers, phosphates, fluospar - 17

21. General and Repair Services and Supplies (45, 47, 50, 52)

a. Barber and beauty; TV, refrigeration and watch repair; photo studios - 170
b. Misc. business services, duplication, detective, bicycle repair, consulting - 171

E. Housefurnishings and Equipment

22. Household Textiles (2)

a. Felt, lace, artificial leather, linen, burlap, ribbon, yarn - 37
b. Drapes, bags, towels, awnings, sails, embroideries, diapers - 40
c. Broad and Narrow Fabrics 35 52%

23. Floor Coverings (29)

a. Woven and tufted carpets, rugs - 36
b. Linoleum - 150 23%

24. Furniture (17)

a. Furniture, lumber and wood products - 41
b. Household furniture, non-wood - 45
c. Wood and metal partitions, shelving, venitial blinds - 46

25. Appliances (41, 60)

a. Sewing machines, food appliances, wood working machines, printing - 109
b. Vacuums, dishwashers - 116
c. Household appliances, cooking refrigeration, laundry, grinders - 123
d. Lamps and lights - 124
e. Mechanical measuring devices, thermostats - 142
f. Generators and motors - 120

26. Kitchenware (65)

a. China, tableware, and other pottery - 80
b. Cutlery - 98 56%
c. Silverware - 147 25%

27. Misc. Housewares (79)

a. Awnings, brush handles, film and tubs, mis. plastics - 74
b. Handtools and other hardware - 98 44%
c. Hangers, springs, barbed wire - 99
d. Engraving, polishing, safes and vaults - 101
e. Farm machinery - 103
f. Typewriters and balances and other office machinery - 115
g. Cards, bells and Xmas tree lights - 131
h. Feathers, buttons, pins, brooms, candles - 150 77%
i. Wall light switches, transformers - 119
j. Batteries - 129 2%
k. Industrial chemcials - 55
l. Misc. plastics - 62
m. Clocks - 146 23%

F. Clothing and Materials

28. Apparel (3, 15, 16, 17, 30, 42, 43, 44, 57, 68, 69, 70, 79, 92, 93, 94, 107, 120, 121, 122, 135, 149, 150, 151, 159, 167)

a. Outerware, underware, hosiery (knit goods) - 38
b. Shirts, blouses, coats, suits, furgoods, hats and caps and gloves - 39
c. Bread and Narrow Fabrics - 35 48%

29. Footwear and Accessories (18, 28, 23, 24, 25, 27, 45, 50, 51, 52, 54, 55, 71, 75, 77, 95, 100, 101, 102, 104, 105, 123, 128, 129, 130, 132, 133, 152, 156, 158)

a. Rubberfootwear, bags and baloons - 73
b. Leather footwear - 76
c. Other leather, i.e., luggage, handbags, saddlery - 77

30. Jewelry and watches (26, 53, 76, 103, 131, 157)

a. Watches,-- 146 77%
b. Jewelry - 147 75%

G. Transportation

31. Autos, parts and repairs (2, 5, 22, 23)

a. Tires and inner tubes - 72
b. Carburator - 117
c. Batteries - 129 98%
d. Electrical equipment for internal combustion engines - 130
e. Motor vehicles and parts - 133
f. Auto repair - 173
g. Gasoline - 69

32. Airlines (27)

a. Private aircraft - 134
b. Aircraft equipment - 136
c. Airlines - 155

33. Railroads (26)

a. Railroads - 151

34. Busses, Intracity and Other Intercity (28, 29, 30, 31, 24, 33)

a. Busses - 152

35. Other Transportation (34, 35, 36, 37)

a. Motorcycles, bicycles and snowmobiles - 139
b. Mobile homes, trailers - 140
c. Boats and repair - 137
d. Outboard motors - 102

H. Medical Care

36. Medical Services (2, 6, 10)

a. Physicians, dentists, chiropracters, rest homes - 175

37. Medical Equipment and Drugs (14, 21)

a. Drugs - 66
b. Optical and ophthalmic - 143
c. Medical and surgical instruments, dental - 144

I. Personal Care

38. Toiletry Items (Personal Services and Supplies) 22

a. Perfumes and Cosmetics - 67 51%

J. Recreation

39. TV, Radio, and Musical (2)

a. Radio and TV receiving - 125
b. Phonograph records - 126
c. Radio and TV electric tubes, picture tubes - 128
d. Musical instruments - 148 12%

40. Hobbies and Photography (23)

a. Photographic equipment - 145

41. Sports and Sporting Goods (16, 18, 22)

a. Sporting Equipment - 148 25%
b. Small arms and ammo - 21 and 22

42. Toys and Play Equipment (29)

a. Toys - 148 63%

43. Other Recreation (37, 38, 14, 15, 17)

a. Motion pictures and amusements - 174

K. Reading

44. Newspapers (2)

a. Newspaper publishing and Printing - 52

45. Books, magazines and Periodicals (3, 4, 8)

a. Books, periodicals, misc. - 53

L. Education

46. Schools (9)

a. Blank books and looseleaf binders - 54
b. Private schools and nonprofit organizations - 176

M. All Other Services

47. Insurance (16, 20)

a. Insurance - 166

48. Other Services (14, 28)

a. Advertising, legal, accounting - 172
b. Post office - 177
c. Federal Gov't. Enterprises - 178

FOOTNOTES

1. Five Digit Product Shipments Adjusted for Exports and Imports 1958-69, Inter-Industry Forecasting Project, Bureau of Business and Economic Research, University of Maryland, College Park, Maryland.

2. Industrial Composition of Personal Consumption Expenditures, By PCE Category, in Producers and Purchasers Prices, 1963, mimeograph from the Inter-Industry Economics Division, Bureau of Economic Analysis, U.S. Department of Commerce.

SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

1. Report No.

W

5. Report D

STUDIES IN ENVIRONMENT - Volume IV - Consumption Differentials and the Environment

6

8. Performing Organization Report No.

Mary Beth Olsen, Ethan Bickelhaupt, Donnie Grimsley, Cherie Lewis, Pamela Scott

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Fundamentally, pollution is a direct reflection of the behavioral patterns of the consuming public. [illegible] In order to achieve long lasting positive reductions of pollutants, basic attitudinal changes must be effected toward what goods and services are demanded, in what quantities, as well as attitudes toward usage and disposal of these items. It is this area in which this report makes initial contributions.

Through the use of a mathematical model, both direct and indirect industrial pollution generated by fluxuations of the entire economy are tied to behavioral patterns of the consuming public. The model studies consumer behavior patterns from three viewpoints: income of family, age of head of family, and regional location of family within the United States. The methodology relates 126 final consumption industry groupings to 48 consumer item (product) groupings of the National Conference Board's taxonomy. The heart of the methodology employs the Resources for the Future's "National Pollution Model", basically an input-output plus residual technique.

Findings focus on most polluting industries, and the pollution associated characteristics of sub-groups of the U.S. population.

Consumer pollution, input-output model, consumption model

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